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THROUGHOUT THE HISTORY OF the United States Navy, surviving the peace has proved as difficult as winning the war. At the conclusion of the worldwide carnage of 1914–1918, most Americans turned their backs on the prospect of armed conflict and foreign entanglements. In this political environment the Navy Department searched for ways to demonstrate its peacetime utility and its continuing financial need to a war-weary public and skeptical Congress. So it was that after displaying considerable promise during the Great War, oceanography figured prominently in one of the political survival strategies adopted by the Navy during the early 1920s and became a regular part of the fleet's mission through the financially difficult interwar years. The commitment first made by both the Navy and civilian science between 1914 and 1924, as well as their desire to cooperate (for both idealistic and practical reasons), permitted a quick response to the maritime challenges posed by the Axis twenty-one years after the guns went silent on the Western Front in 1918.

World War I and the U-boat provided a catalyst that accelerated American naval oceanographic studies, dramatically altered scientific practice, and

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profoundly affected the selection of new subjects for ocean science. Wartime projects under the aegis of the Naval Consulting Board and the National Academy of Sciences' National Research Council (or NRC) drew scientists from a great many specialties out of their normal academic or industrial environments to address the critical needs of the operational forces.[1] Antisubmarine warfare (ASW) and pro-submarine investigations provided considerable incentive and added new avenues to the study of the ocean depths, avenues that some scientists continued to pursue after the war ended.[2] In the course of this work, oceanography came of age in America and demonstrated its value to the United States Navy.

Between 1914 and 1918 oceanographic ASW research, as opposed to pro-submarine investigations, dominated the attention of the allied scientists who were asked to devise an effective way to neutralize the German submarine threat. In the United States this effort was organized along two parallel lines, one directed by the Navy and the other by the civilian scientific community at the request of the Navy Department.

In the Navy, the primary effort to draft scientists into the war effort was represented by the Naval Consulting Board (NCB), created in July 1915.[3] Secretary of the Navy Josephus Daniels, who established the Board, placed it under the direction of the famous inventor Thomas A. Edison to evaluate suggestions and inventions offered to improve the Navy's performance should America become involved in the war. Throughout its existence, the Naval Consulting Board remained an advisory body to the Secretary of the Navy. It could encourage research into and development of systems like the magnetic submarine detector invented by physicist Vannevar Bush.[4] But, having no research and development money of its own, the Board and its committees remained merely advocates, urging Secretary Daniels to support promising developments in the private sector.[5]

When the United States actually became a belligerent in 1917, Daniels expanded the Board's powers, and it instituted special committees to explore difficult wartime problems. As early as 26 October 1915 the Secretary had ordered the Navy's Bureau of Construction and Repair to investigate a means of detecting submerged submarines from a surface ship. One week after President Woodrow Wilson severed relations with Germany on 3 February 1917, the Naval Consulting Board created a Committee on Special Problems to coordinate naval and civilian efforts on U-boat detection and destruction, including those initiated by the naval bureaus and those sponsored by the National Research Council.[6] This committee, chaired by Board member Lawrence Addicks, divided the problem of ASW into its component parts for consideration by subcommittees. These subdivisions of the Addicks committee explored all available ASW tactics and techniques, including underwater sound,

nets, magnetic and electrical means, underwater searchlights and visibility, and air attack.[7]

To focus naval resources on the best areas of inquiry, Edison's staff invited a group of experts in ASW-related fields, nominated by the NCB, to gather in New York at the Engineering Society's building on 3 March 1917. In their conclusions these specialists recommended underwater sound and echo-ranging as the most promising avenue of exploration. Physics and physical oceanography immediately became vital to the national war effort. One month later the Naval Consulting Board recommended that Daniels divert $10,000 earmarked for the establishment of the new Naval Research Laboratory to the use of the Committee on Special Problems. The U-boat threat had become so important that the Board voted unanimously to place research on submarine detection above the creation of the long-desired NRL.[8]

After the New York conference, the NCB's Subcommittee on Submarine Detection by Sound gave its support to the promising work of the Submarine Signal Company of Boston, a specialist in underwater sound.[9] This firm had incorporated the powerful oscillator developed by Reginald A. Fessenden into a practical device for detecting icebergs and had demonstrated the possibility of determining ocean depth by means of echo-ranging. When the company's first U-boat detection device failed to impress the Navy Department, the NCB encouraged cooperative research by Submarine Signal, General Electric, and Western Electric at Western Electric's facility in Nahant, Massachusetts. Armed with the most complete knowledge science had to offer, the three firms explored various methods of submarine detection, including echo-ranging and promising hydrophone listening devices.

On the civilian side, the National Research Council furthered cooperation and education on the U-boat detection problem by arranging an international conference in June 1917. The council brought to Washington British experts, including the 1908 Nobel laureate physicist Sir Ernest Rutherford, and their French military counterparts, Majors Fabry and Abraham, and Captain Dupray, who were all trained in the pioneering underwater sound techniques of Paul Langevin and the Swiss Constantin Chilowsky. Like the Naval Consulting Board, which had set three commercial firms to working together in Massachusetts, the NRC supported the creation of the Naval Experimental Station in New London, Connecticut, recruiting for it, among others, Robert Millikan of the University of Chicago and the University of Wisconsin's Max Mason to apply their skills to the ASW problem.* Mason was to provide the creative

* Millikan (1868–1953), a physicist who first isolated (in 1911) the electron, won the 1923 Nobel Prize in physics. Mason (1877–1961), a mathematician, was known for (beside ASW inventions) research in calculus of variations and electromagnetic theory.

genius behind several generations of the Navy's "M," or multiple-tube, passive submarine sensors. This apparatus focused sound to ascertain its source; to determine the direction from which the sound came, the operator needed only to seek the maximum output on his earphones by turning a dial.[10]

In addition, the National Academy of Sciences collected scientific intelligence from around the world through Research Information Service offices established by the NRC in Washington, Rome, London, and Paris. Information from participating scientists kept the NRC and the Navy abreast of the latest work done on underwater sound and echo-ranging.[11]

Days before the Armistice, American naval representatives journeyed to Paris for a conference on "supersonics," a term which then referred to underwater echo-ranging. Meeting with the French and British between 19 and 22 October 1918, the Americans received more complete information about Langevin's progress in piezoelectric research as well as an underwater sound transmission device that the French had designed to apply the theories developed by Chilowsky and Langevin.[12]

Reports on the conference were prepared by both the American associate scientific attaché in Paris, Karl T. Compton, and one of the leading scientists in the American effort to build an operational "supersonic" device, Professor J.H. Morecroft of Columbia University.[13] They not only described in great detail the performance of the Langevin device but also demonstrated a heightened appreciation of the properties of the ocean that affect undersea sound transmission. In the course of American experiments in underwater signaling, Compton "noticed, as have all those who have been engaged in listening under water, great irregularities in transmission due certainly to the influence of the water medium." He went on to discuss the viscosity of the water, its temperature, the presence of marine life and debris, and the effect of bubbles on sound transmission.[14]

Oceanography had quickly become indispensable to modern ASW. In the short period of time America actually participated in World War I, scientific research helped keep the U-boats at bay. When the advent of convoys in 1917 required some capability for detecting U-boats, industry in the United States rapidly manufactured three thousand SC hydrophones, with their characteristic rotating T-bar and stethoscope listening set. Although primitive, these detectors, protruding from the bottom of American and British submarine chasers, forced German submarine commanders to take greater care in approaching convoys. In many instances, however, developments took longer to reach the operational forces. Vannevar Bush's device for detecting a U-boat as it broke a magnetic field was barely installed in British minesweepers for testing before the conflict ended. Nonetheless, these and other wartime experiences identified science as an

important partner in modern naval warfare. As historian A. Hunter Dupree observed many years later, nothing would replace effective weapons, doctrine, and seamanship, but "the very approach to the problem as one that could be solved only by massed and coordinated scientific resources demonstrated clearly that a new era of warfare had arrived and that science had an essential place in it."[15]

What sort of naval warfare lay in the future? In 1919 very few Americans wanted to address that question. Peace and a return to normalcy, not war, reigned uppermost in their minds. In his 1921 inaugural address, President Warren G. Harding reflected the popular American mood when he offered to place the very ambitious 1916 warship construction program on the table at an international naval armaments conference.[16] When Secretary of State Charles Evans Hughes formally proposed the meeting, the sheer cost of war or even a naval arms race, especially one between the United States, Great Britain, and Japan, provoked wide public support for his proposal. Naval building competition, as had occurred between Britain and Imperial Germany before the Great War, was perceived by the voting public as well as by many in the Congress as destabilizing, a waste of resources, and a threat to national security. Hughes also argued that a policy of conciliation combined with a willingness to negotiate would diffuse international tensions, especially with Japan over the Anglo-American presence in the western Pacific, and with Britain over naval supremacy.

The conference that began in Washington on 12 November 1921 halted the substantial American construction program authorized five years before and established a fixed ratio of relative battleship strength between Britain, the United States, Japan, France, and Italy. These limits and other restrictions accepted by the signatories at the Washington Naval Conference laid the foundation for interwar American naval policy. Congress not only accepted the limits set by the Conference in 1922 but for the next twelve years refused to authorize spending and construction to meet even the minimum force levels permitted by the agreements.[17] As these events unfolded, the Navy struggled both to meet its operational commitments and to convince the public and the Congress of its value in peacetime.

Shortly after the Washington Naval Conference, Dr. Harvey Hayes wrote a memorandum to his supervisor, Captain John Halligan, Jr., officer in charge of the Navy's Engineering Experiment Station in Annapolis. This correspondence, dated 19 February 1923, effectively marks the beginning of a firm naval commitment to modern oceanographic research. A Navy physicist and former Swarthmore physics professor, Hayes had become frustrated with congressional reluctance to provide regular and adequate funding for NRL and had voiced concern about the adverse effect it might have on his underwater sound work

and other projects destined to move to the Laboratory. At the end of his memorandum's second paragraph, he asserted that "the Bellevue Station [NRL] will never be definitely and adequately supported by Congress until its members are made to realize the importance of military research, as such, or until their interest in the station is aroused through the successful application of the results of these researches for other than military purposes."[18]

Hayes suggested a well publicized commitment to oceanographic research. Scientific and technical experience gained in hunting U-boats during the war might now unlock the nature of the ocean. With a program of this sort, the Navy could leave the war behind and at the same time reach beyond traditional hydrography, navigation aids, and mapmaking to acquire a better understanding of its own natural environment. The same research that would enhance appreciation of the ocean and vastly improve navigation and the safety of ocean travel would also facilitate naval operations, on the surface and submerged.[19]

"In this political environment the Navy Department searched for ways to demonstrate its peacetime utility and its continuing financial need to a war-weary public and a skeptical Congress."

These ideas immediately struck a chord, appealing to those who valued the practical and profitable side of such a postwar policy, as well as to those engaged in the science. Hayes convinced the Navy Department that a program of oceanographic research would enhance its public image by providing tangible evidence of the Navy's peacetime service to the nation. A commitment of this sort might also induce Congress to support more generously and regularly the newly created Naval Research Laboratory, then under construction at Bellevue, on the Potomac River five miles south of the Capitol.

Professor Hayes reasoned that any field of naval research pursued so as to elicit the support of Congress must meet certain criteria. For example, the new endeavor should complement and not interfere with the main mission of NRL, which was to conduct applied research in support of naval operations. Furthermore, the work would have to fall exclusively within the Navy's sphere of influence and be congruent with established naval policies. Most importantly, Hayes wanted to generate, on a regular basis and with a minimum of expense, data valuable enough to attract the attention of civilian scientists and the press. In his historic memo to Halligan, Hayes concluded that "these researches should be undertaken in the field of oceanography."[20] The interdisciplinary nature of this science would attract the attention of a great many talented investigators to the study of the Navy's operational realm. Along with biologists, geologists, chemists, and physicists, the Navy would contribute to human knowledge in a

way that would directly affect the economic welfare of millions. Oceanographic research might easily translate into improved cable communications, easier transportation, and seafood harvests before which the biblical multiplication of the loaves and fishes might pale by comparison.

He suggested further that the Navy mount an oceanographic expedition covering a precisely defined area of the Pacific Ocean. If the Department were carefully to court and select the participating civilian scientists and institutions, the reputations and achievements of those involved would soon make the Navy's project the center of scientific attention. To sustain this credibility and clearly identify the project with the Navy, NRL would publish the results of the expedition in a laboratory contributions series. Hayes felt that this project, if properly organized, would draw financial grants and gifts galore while placing the peacetime Navy and NRL in the limelight.

For Hayes the time seemed perfect for this type of venture. Recent research had provided some of the best supporting technology for oceanography ever developed. The Naval Hydrographic Office and the Bureau of Fisheries of the Department of Commerce could contribute a large portion of the necessary equipment, and the expedition could turn to the Bureau of Engineering for both state-of-the-art communication equipment and a sonic depth finder, or SDF. Hayes had recently developed the SDF for the Navy, based upon his research into active sonar during the war. This device projected the sound generated by a Fessenden oscillator toward the bottom of the ocean and used the time the echo took to return as an indication of depth. Early evaluations conducted by the Navy at the Engineering Experiment Station confirmed the importance of the SDF for both the Navy and the scientific community. At the annual meeting of the National Research Council in April 1922, Harvard geologist William M. Davis had suggested more extensive testing of the SDF, including alterations to the device to permit determination of bottom slope as well as the depth of the ocean at any given point.[21]

To the universal acclaim of the scientific community, Hayes had then used his invention to make the first complete bottom profile of any ocean, during the June 1922 transatlantic crossing of the destroyer *Stewart* (DD 224) from Newport, Rhode Island, to Gibraltar. With Hayes on board, the *Stewart*, under the command of Lieutenant Commander Norman R. Van der Veer, made nine hundred soundings of the ocean bottom to depths beyond three thousand feet. The news of this accomplishment went through the scientific community like a bolt of lightning. As historian Susan Schlee observed, "The results were indeed spectacular. The *Challenger** in her entire three-and-a half year voyage had taken

* HMS *Challenger*'s round-the-world cruise, which began in 1872, gathered physical, geological, biological, and chemical data of great importance to international oceanographic research.

less than three hundred soundings in depths exceeding 1,000 fathoms, and in the same years the Coast Survey considered it a good field season when 100 or so deep soundings were collected."[22] The Navy's new instrument gave scientists their first comprehensive look at the configuration of the ocean floor in all its irregularity. Sound now at last began to reveal what years of work with rope and wire sounding lines had only suggested. Civilian science quickly concluded that the number and range of naval vessels as well as the revolutionary potential of the SDF made the U.S. Navy an indispensable partner in the exploration of the ocean.

To implement his ideas, Hayes looked to the Navy's history for a paradigm. He suggested mounting an expedition not unlike that led by Lieutenant Charles Wilkes nearly a hundred years earlier. The Navy would provide a fully outfitted and manned vessel with accommodations for approximately fifty government and civilian scientists. Specialists in the various disciplines of ocean science would assist the Navy in selecting regions for investigation, and both the universities and research institutions sponsoring the participants would help defray the expenses. Hayes insisted upon naval direction in every phase of preparation, in order that the maximum publicity and popular goodwill might accrue to the Navy for the expedition and its successes. Although prominent academic institutions and the National Academy of Sciences would certainly assist in the selection of participating scientists, final invitations to join the expedition would come from the Secretary of the Navy.

Hayes concluded his memorandum by insisting that his proposition went beyond the Navy or any single expedition. In an age of naval armaments treaties, force reductions, and budget cutbacks, the Navy needed the financial and professional support of the academic community and private research institutions. It would also have to draw on the resources and cooperation of other federal agencies. If the Navy made a determined effort, Hayes felt, an oceanography program could take on a life of its own: "I am of the opinion that if the proposed research work is once started by the Navy that it will continue indefinitely, and, if this proves true there is no doubt but that the researches will suggest many improvements in the apparatus that will result in continuously making the work more effective. It is along these lines that the Bellevue Station will cooperate."[23]

As it went through channels, forwarded by Halligan, the Hayes memo gathered a cluster of positive endorsements from all quarters. The Burean of Navigation applauded Hayes's initiative, and Captain Frederic B. Bassett, Hydrographer of the Navy, enthusiastically supported the proposal, citing eight precedents for Navy-supported oceanographic research. Assistant Secretary of the Navy Theodore Roosevelt, Jr., noted that the existing operating force plan made Hayes's recommendations impossible but insisted that the Chief of Naval

Operations allow for such a project in a revised operations plan in the near future.[24]

With his memorandum Harvey Hayes demonstrated political sensitivity, loyalty to the Navy, personal ambition, and a talent for weaving all of these disparate qualities into a practical and appealing policy proposal. The importance of his proposition did not lie in its suggestion that the Navy commit itself to science; with a tradition that included Wilkes's leadership of the United States Exploring Expedition of 1838–1842 and Lieutenant Matthew Fontaine Maury's groundbreaking work on physical oceanography, the Navy and the ocean sciences were old friends.[25] The importance of the memorandum lay in its new perspective on the future and in its author's call for a broader and deeper collaboration between ocean science and the Navy.

While saving NRL and advancing his own work provided a personal catalyst, a more productive naval-scientific relationship emerges from the memorandum as the author's central ambition. Hayes suggested the need to go beyond the necessary and useful work of developing charts, instruments, and aids to navigation at the Hydrographic Office and the Naval Observatory: he demanded a higher priority for basic research in the Navy. With naval resources, scientists in and out of federal service could achieve fundamental insights into the geology, chemistry, and physical attributes of the ocean environment, for the benefit of naval operations and the general public. All of his proposals pointed toward a long-term, mutually beneficial partnership in basic research between the Navy and the civilian professionals dedicated to the perennial accumulation and analysis of oceanographic data. The activities Hayes proposed offered the Navy a financial benefit as well: if it stood on the cutting edge of oceanographic knowledge, the Navy would have less trouble procuring funding support for combat readiness and the Hydrographic Office's vital chartmaking services.

Professor Hayes could not have laid sole claim to these ideas, nor in some cases could he have taken credit for presenting them first. But unlike scientists who had suggested this kind of naval commitment in the past, Hayes had the advantage of making the suggestion from within the Navy and of formulating it as a practical response to political and financial crisis. His timing, his experience within the Navy Department, and his argument that oceanographic research would not only provide knowledge but practical solutions to pressing naval problems made his proposal very appealing to all parties, whatever their motives or interests.

The excitement caused by the potential of the depth finder and Hayes's February 1923 memorandum to Captain Halligan prompted many within the scientific community to recommend immediate use of the SDF for oceanographic exploration. Ocean bottom profiles similar to those taken by the *Stewart*

in the Atlantic seemed the natural course. Professor Davis at Harvard suggested naval participation in the second Pan-Pacific Science Congress, scheduled for Sydney and Melbourne, Australia, in August 1923. Secretary of the Navy Edwin Denby had received notice from the State Department on 22 January that Great Britain had asked the U.S. Navy to participate. Davis submitted that a naval vessel equipped with an SDF could conduct a series of bottom profiles while en route to the symposium. He predicted that "if successfully carried through there can be no doubt that the achievement would be the outstanding feature of the Congress. It would be a handsome and generous testimony on the part of our Navy to the importance of the Congress and it would give a great impulse to the exploration of the oceans. It would receive the recognition that it would deserve."[26] Nevin M. Fenneman, chairman of the NRC's Division of Geology and Geography, echoed Davis's opinions in a letter to Denby on 30 April, saying that were there to be naval participation he "might be pardoned for a certain amount of pride in the traditional value of the American Navy as an ally to scientific research."[27]

"By suddenly providing a way to examine the invisible more closely, [the sonic depth finder] offered both material and psychological benefits. . . . [It] turned on an acoustic 'light' in a very dark room."

To the acclaim of the Pan-Pacific Congress's organizers, Secretary Denby agreed to allow the Navy to participate. After initially rejecting the twenty-year-old *Denver* (reclassified in 1921 as CL 16) for the job and investigating the availability of funds for the enterprise, he ordered the newly commissioned light cruiser *Milwaukee* (CL 5) to make the trip, with Captain William C. Asserson in command. Captain Bassett, as chief of the Navy Hydrographic Office, instructed Asserson to make a series of ocean bottom profiles en route to Australia and, at the Congress, give a presentation on the SDF and its operation using the profiles as exhibits. Bassett assured him that he could count on the assistance of Dr. Alfred Brooks of the Department of the Interior and of geologist William H. Hobbs of the University of Michigan.[28]

The SDF presentation was one of the highlights of the Congress. When he read his paper on 27 August 1923, Captain Asserson illustrated his comments with a chart showing a line of soundings and bottom profiles from the Columbia River in the American Northwest to Sydney, via Honolulu, Samoa, and the Fiji Islands. The delegates took considerable interest and afterward came aboard *Milwaukee* to pepper him with questions about the SDF.[29] If the Navy and Harvey Hayes wanted public attention, the summer voyage of the USS *Milwaukee* to Australia gave them a very satisfactory first taste.

William Hobbs at Michigan shared Hayes's desire to launch an extensive oceanographic program in cooperation with the Navy; in 1921 they had tested the SDF together in the western Pacific, and Hobbs had long supported collaborative research ventures. In 1920 he had suggested an oceanographic expedition in cooperation with the Navy; the Chief of Naval Operations, Rear Admiral Robert E. Coontz, had looked favorably upon the proposal. Hobbs had then lobbied the Geological Society of America and the National Research Council, and he now saw in the Hayes recommendations an opportunity to launch the project with considerable support from the Navy and the scientific community. In December 1923 he visited Secretary Denby, following up on 7 January with a letter offering specific proposals for cooperative research.

In his January 1924 letter, Hobbs suggested the Pacific and Caribbean as the focuses of the joint oceanographic expedition and offered some ideas on organization and logistical support. The Navy would supply the ship, officers, crew, scientific library, and a considerable amount of instrumentation, including the remarkable SDF. Research institutions and universities sponsoring the participants would pay salaries and meet the cost of food for the voyage. Hobbs insisted upon a comprehensive approach to the research, embracing geology, anthropological fieldwork, zoology, and botany, as well as extraordinary efforts to collect the best oceanographic data possible. The SDF would take bottom contour readings; scientists would measure waves, employ seismic instruments, and acquire an apparatus for rock-core drilling to secure deep samples from Pacific coral reefs.[30]

In February, Denby instructed the Hydrographic Office to seek the advice of the National Research Council on the Hobbs and Hayes proposals. Captain Bassett, the Hydrographer, accordingly asked the opinion of the NRC on both the kind of oceanographic exploration the Navy should pursue and the merit of the Hobbs proposal;[31] Gano Dunn, chairman of the NRC Executive Board, referred the questions to the Division of Foreign Relations' Committee on Pacific Investigations. Herbert E. Gregory, director of the Bishop Museum in Honolulu, chaired this committee, and Albert Barrows, secretary of the Division of Foreign Relations, was the Division's liaison in Washington, D.C.

Barrows immediately set to work collecting opinions from the committee members, including Gregory, John C. Merriam of the Carnegie Institution of Washington, and Thomas Wayland Vaughan, incoming director of the Scripps Institution for Biological Research in La Jolla, California.[32] All quickly communicated their enthusiasm for cooperative oceanographic work with the Navy (although a few had reservations about the particulars of Hobbs's proposal). Indeed, Walter T. Swingle of the Department of Agriculture commented that he had "long believed that it was a great mistake not to do a certain amount of scientific work under the auspices of the Navy Department."[33] Barton W.

Evermann of the California Academy of Sciences praised Hobbs's broad definition of the fundamental problems and the importance of cooperation with the Navy.[34] From the U.S. Coast and Geodetic Survey in Washington, William Bowie recommended strong direction by a single person or agency to provide central authority and a clear definition of the expedition's goals.[35]

Parallel inquiries conducted by Bassett's second in command, Commander Guy Davis, with Professor Andrew Lawson, chairman of the NRC Division of Geology and Geography, revealed that a major survey, or "reconnaissance," voyage might have its advantages.[36] On 29 February 1924 Davis asked Lawson, who taught mineralogy and geology at the University of California, for his views on cooperative oceanographic ventures; Lawson responded with a richly detailed seven-page memorandum. He agreed with Hayes that the Navy would perform a public service by pursuing oceanographic research while pursuing its own professional and financial needs in the process. He described an involved program of geological, physical, chemical, and biological studies requiring a staff of thirty-three scientists, observers, and assistants. Lawson suggested a program of five years' duration to investigate the continental shelf off the American West Coast and its relation to the continent and to the ocean bottom. The project would include mapping the region, along with physical and biological investigations. The Navy and its associates in this endeavor would have to impose strict financial and geographic limits on the project. He estimated that if provided with the proper laboratories, personnel, and equipment, to the tune of $90,000, the Navy and civilian science would emerge with scientifically worthwhile and publicly impressive results. As he later commented in this connection to the 1924 NRC annual meeting, "Any comprehensive plan of oceanography which the Navy may adopt will require the advice, if not the direction, of a disinterested body representing the various sciences concerned, and it would be difficult to find a more appropriate and competent body than the Division of Geology and Geography of the National Research Council. The proposal which the Navy has in contemplation is of the greatest importance for the extension of scientific knowledge in a domain where our knowledge is very scant."[37]

As the responses solicited by Bassett and Davis accumulated, the difficulty of properly organizing and financing a single, comprehensive expedition emerged as the central concern. Leonhard Stejneger of the Smithsonian Institution informed Barrows and Dunn (of the NRC Executive Board) that although a large expedition sounded attractive, he doubted its feasibility and long-term value. Stejneger suggested instead a series of smaller, more focused projects in conjunction with the Navy; these, he argued, would lend themselves to results of higher quality at affordable cost. He praised the work done on the famous voyage of HMS *Challenger* but insisted that general reconnaissance projects could not yield as much significant data on the immense Pacific Ocean as would

numerous smaller, focused, and carefully organized expeditions.[38] Marine biologist William E. Ritter (director of the Scripps Institution) heartily agreed with that view, and Thomas Wayland Vaughan, an NRC committee member who would succeed Ritter at Scripps, also feared that a single, major exploratory expedition would fall short whereas a series of briefer, well focused and financed ventures might succeed gratifyingly. Vaughan went a step further, recommending that the Secretary of the Navy call a general conference to define the character and extent of any expeditions the service chose to sponsor.

Barrows and Gano Dunn communicated to Captain Bassett the consensus of these opinions, that the multiple expeditions and the strong central direction preferred by most NRC scientists more closely corresponded to some of Professor Hayes's suggestions than to the plan put forth by William Hobbs. The NRC's advice also provided the Navy a way to define more precisely the action it planned to take. Secretary Denby and Assistant Secretary Roosevelt came to the conclusion that the Navy should pursue oceanographic studies in a way that would provide the broadest possible benefit to both the nation and the Navy.

With the approval of the incoming Secretary of the Navy, Curtis D. Wilbur, and on the advice of Vaughan, Roosevelt began preparations to convene a federal interagency conference on oceanography (ICO) in Washington. He wanted the participants to suggest the most profitable application of federal, and particularly naval, resources; in fact the proposals made at the ICO would determine the nature of the naval commitment to oceanographic research for the next two decades.

On 2 June 1924, Roosevelt, then acting Secretary of the Navy, sent out invitations to prominent civilian scientists, scientific institutions, government agencies, and also naval bureaus and activities. Following the suggestions of Harvey Hayes, Roosevelt made sure the Navy maintained a high profile for the sake of political utility and public relations but did not lose sight of the genuine value of the scientific exploration under consideration. In his invitation he committed the Navy to appeal to Congress for funds to finance the exploration the interagency conference might recommend.[39] Roosevelt received positive responses to his invitation from sixty-one scientists and federal officials representing twelve different government agencies and private institutions.

The conference opened at the Navy Department on 1 July 1924 under the able direction of the Hydrographer of the Navy, Captain Bassett, in the capacity of "Secretary General." Harvey Hayes attended, as a representative of the Navy's Bureau of Engineering. Other major participants included George Littlehales from the Hydrographic Office, Commander H.S. Howard of the Bureau of Construction and Repair, Austin Clark from the Smithsonian, William Bowie and six colleagues representing the committees of the National Academy of Sciences and the National Research Council, and Dr. Henry Bryant Bigelow

of the Museum of Comparative Zoology at Harvard, who appeared on behalf of the Bureau of Fisheries. The assembled scientists and government leaders developed the Hayes initiative well beyond the intent of the original February 1923 memorandum. In their report to Secretary Wilbur, the conference participants emphasized the great utility of the proposed investigations. Of the objectives they defined, improving humanity through discovery and exploration and preserving human life were, respectively, third and fourth; learning how to use the resources of the sea and improving communication through submarine cable and radio emerged as the primary goals.

How should the scientific community accomplish these objectives? The consensus at the 1924 meeting counseled against another *Challenger* expedition and encouraged instead an "intensive study of selected regions and problems," with the Gulf of Mexico–Caribbean area first on the list. The ICO requested at least a single vessel and crew from the Navy, and hoped for more, to explore this body of water and the areas immediately adjacent, from the North Atlantic down to the Canal Zone. Thereafter, the work could expand into the Pacific, with an initial emphasis on the northern portions of that ocean. A committee of specialists at the ICO estimated that instruments and equipment would cost approximately $50,000, with the Navy, other federal agencies, and private institutions sharing the burden. They envisioned a scientific staff of at least nine: a physical oceanographer, a biologist, a geologist, and about six technicians and assistants. The first three had to be scientists of the very highest caliber, whose home institutions would absorb their basic expenses, save for subsistence and round-trip travel. The projected total cost of the project would be $57,500.

Although the conference placed the greatest emphasis on geology and geophysics, the problems given priority as the major concerns for the near future represented all of the major disciplines within oceanography. The invention of the SDF opened many opportunities to study the configuration of the ocean bottom. Those interested in the Earth's crust no longer suffered from blindness. Eager conference participants wanted to study "changes in the size and shape of the bottoms of the seas, such as shifting of shorelines, warping of the margins of continents and submarine upheavals and dislocations." Greater understanding of the sediments that compose the ocean bottom as well as violent changes like earthquakes and volcanoes now appeared to scientists in the broader context of ocean bottom profiles and some of the first regional maps of the ocean floor. To this the physicists added their desire to gain a greater appreciation of gravity variation in the Caribbean and Pacific area. Other goals included the study of currents, both shallow and deep water, the temperature, salinity, density, and general chemistry of seawater, and the interaction of the atmosphere with the surface of the ocean.

In an era of dramatically reduced spending on the armed forces, the final conference report dared to express optimism and a sense of permanence: "The recommendations embodied in this report are based upon the expectation that research in oceanography will take a permanent place among the activities of the Navy." The report recommended that the Secretary of the Navy consider appointing a continuing advisory committee to serve as the program's advocate in the budget process and to fashion an efficient administrative system for its early stages. Captain Bassett and his assistant at the Hydrographic Office, Lieutenant Commander George E. Brandt, received nomination and quick approval as chairman and secretary of the new committee. Other participants in the ICO who agreed to serve included Captain R.O. Crisp of the U.S. Coast Guard, Lieutenant Colonel C.A. Seoane of the Army Signal Corps, Littlehales of the Hydrographic Office, the NRC's Bowie and David White, Clark of the Smithsonian, Ball of Agriculture, and Bigelow at Harvard. Captain J.P. Ault of the Carnegie Institution in Washington, master of the nonmagnetic research vessel *Carnegie*, also joined the committee; his advice would prove invaluable in the practical preparations for going to sea. The scientists wanted the entire program referred to as "Maury U.S. Naval Oceanographic Research," after the premiere ocean scientist in the service's history, Matthew Fontaine Maury.

The most remarkable aspect of the conference emerges from the notes taken on the proceedings by Bassett as Secretary General. A genuine excitement took hold of those in attendance. Federal agencies envisioned harvesting the sea with greater efficiency, making navigation safer, promoting communication and submarine cable projects, and countless other productive ventures. Ocean scientists, who perennially suffered from inadequate funding and the lack of suitable ships for research at sea, realized the potential in cooperative work with the Navy and other federal agencies. In his effort to sustain the Naval Research Laboratory and promote naval research generally, Harvey Hayes had unleashed a remarkable amount of pent-up enthusiasm, determination, and energy.

Development of the SDF had played a critical role. Usually the effect of an instrument, no matter how useful, remains limited to the task at hand. It liberates the scientist from repetitive chores, makes an awkward task easier, or helps overcome physical obstacles. The sonic depth finder did all of this and more for those studying the ocean. By suddenly providing a way to examine the invisible more closely, it offered both material and psychological benefits. For centuries scientists had had to rely on rope, wire, gathering devices, and weights to sense the topography of the ocean bottom. While it did not preclude the continued use of these tools to attain certain research goals, the SDF provided a picture of contours of the earth that had lain submerged and beyond the reach of human eyes for centuries. It did not make the ocean transparent, but to a remarkable degree it freed a captive scientific community from severe physical restraints

and opened a wide array of promising research opportunities. With the SDF, Harvey Hayes turned on an acoustic "light" in a very dark room. His invention not only permitted scientists to see but awakened them to new, stunning possibilities for oceanography. In the years immediately following the Great War, the United States Navy was determined to pursue those possibilities for itself and the country.

Oceanography came of age in both Europe and the United States by serving critical purposes. For northern Europe, it was fisheries management and economic necessity that funded and drove this type of research; in the United States, the U-boat threat of the Great War mobilized the resources necessary to initiate and support large-scale oceanographic studies. As underwater sound emerged as the most promising method of submarine detection, the Naval Consulting Board and the National Research Council realized that effective ASW required sustained research, pure and applied, in various aspects of oceanography.

After the war, the Navy turned to oceanography as a way to survive the peace and contend with contracting budgets. The worldwide activities of the Hydrographic Office kept the service involved in oceanography in the early postwar period. While certainly significant and important, these efforts did not, however, emerge from the background until the Hayes memorandum of 19 February 1923. In it the former Swarthmore physicist offered a practical, concrete program to broaden the Navy's popular and political appeal by demonstrating that it could educate Americans in peace as well as destroy an enemy in war. In making these proposals, Hayes sought to induce the Navy to work for a deeper appreciation of its own operating environment. While it was reasonable and expedient for a navy to explore the ocean, these proposals also served Hayes and his underwater sound program in a very practical way. If oceanography could capture the imagination and resources of the Navy, the sound program at the Engineering Experiment Station would receive an adequately funded new facility at the Naval Research Laboratory in Anacostia to continue ocean research with important antisubmarine applications.

In 1924 at the Interagency Conference on Oceanography, the Navy Department embraced the suggestions made by Hayes and the NRC's Andrew Lawson, committing itself to oceanographic research. With the ICO the Navy took its first step toward formulating a coherent research program in oceanography to support its mission.

Unfortunately, the program would thereafter nearly die. The fiscally conservative Calvin Coolidge refused to approach Congress for funding to carry out the ICO's recommendations. In spite of this setback, the interwar years still marked the beginning of the Navy's commitment to the ocean sciences, because

supporters of the Navy's fledgling oceanographic effort and the ICO agenda averted complete disaster by departing from customary institutional relationships and procedures. Consultations, informal agreements, and personal contacts partially offset the effect of denied centralized sponsorship by skillfully combining the physical and human assets of the Hydrographic Office with those of the civilian oceanographic community. In this way, there evolved before the Second World War a *common practice* that would sustain important research reflecting scientific and naval cooperative priorities in the Pacific Ocean, the Caribbean Sea, and the Gulf of Mexico.

Notes

1. Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: Dutton, 1973), p. 265; and Submarine Signal Co. to Hydrographic Office, #17518 of 1 April 1909, box 193, Naval Hydrographic Office General Correspondence 1907–1924 [hereafter Hydro-Gencorr], record group [RG] 37, National Archives [NA].

2. The term "pro-submarine" denotes research undertaken to enhance the offensive and defensive capabilities of submarines.

3. A. Hunter Dupree, *Science and the Federal Government: A History of Politics and Activities to 1940* (Cambridge, Mass.: Belknap Press of the Harvard Univ. Press, 1957), pp. 318–9; and Lloyd N. Scott, *Naval Consulting Board of the United States* (Washington, D.C.: Navy Department, 1920).

4. Bush was a physicist working for J. P. Morgan's American Radio and Research Corporation of Medford, Massachusetts. During World War II he would direct the National Defense Research Council and later the Office of Scientific Research and Development. For further information on this device, which never detected a U-boat in operational use but was successfully tested in America and Great Britain and was deployed in British submarine chasers, see Vannevar Bush, *Pieces of the Action* (New York: Morrow, 1970), pp. 72ff.

5. Thomas Robins (secretary of the Naval Consulting Board [NCB]) to Secretary Daniels, NCB to Daniels, and NCB to Daniels, 18 March 1918, 22 May 1918, 23 May 1918, respectively, box 47, NCB, Navy Department, Correspondence Files [hereafter NCB 1915–1923], RG 80, NA.

6. In 1916 the National Academy of Sciences, at the request of President Woodrow Wilson, established the National Research Council, or NRC, to facilitate research by assembling committees of scientific and technical experts in many war-related fields. George E. Hale, Chairman of the NRC, to President Wilson, 26 March 1918; Wilson to Hale, 19 April 1918; Hale to Wilson, 22 April 1918; Wilson to Hale, 8 May 1918; Hale to Wilson, 10 May 1918; and J. F. Tumulty (secretary to the president) to Hale, 13 May 1918, all in folder, "Relationship between NAS and NRC, Executive Board," Science Advisory Board, National Academy of Sciences [hereafter NAS] Archive, Washington, D.C. These documents relate to the creation of the NRC by executive order and its official relationship to the agencies of the federal government. See also Dupree, pp. 327-8.

7. Schlee, p. 245; "Problems Assigned to the Board by Secretary Daniels . . . ," 26 October 1915 and 10 February 1917, box 47, NCB 1915–1923, RG 80, NA; Scott, pp. 14–5, 67–83; Daniels to the NCB, 7 February 1917; Daniels to the Bureau of Construction and Repair, 26 October 1915; and Daniels to the NCB, 10 February 1917, box 47, NCB 1915–1923, RG 80, NA.

Daniels felt the pressure of editorial columns criticizing his lack of success with the ASW campaign; even scientific journals and magazines took up the critical chorus (editorial, *Scientific American*, 11 August 1917, box 47, NCB 1915–1923, RG 80, NA).

8. Robins to Daniels, 13 April 1917, box 47, NCB 1915–1923, RG 80, NA.

9. For a general discussion of the underwater sound efforts of the Submarine Signal Co., the ancestor of the modern Raytheon Corporation, see *Submarine Signal Log* (Raytheon, 1963), box 3, Marvin Lasky Papers, RC 21-5, Navy Laboratories Archive, David Taylor Research Center, Carderock, Md. The subcommittee was part of the Special Problems committee.

10. Schlee, pp. 246ff. After the war, only the Navy's underwater sound team, under the direction of Dr. Harvey C. Hayes, transferred from the Engineering Experiment Station in Annapolis to NRL in Anacostia, and the Submarine Signal Company remained in the underwater acoustics business. Daniel J. Kevles, *The Physicists* (New York: Alfred Knopf, 1978), pp. 118–24; Robert H. Kargon, *The Rise of Robert Millikan: Portrait*

of a Life in American Science (Ithaca, N.Y.: Cornell Univ. Press, 1982), pp. 86–7; Scott, pp. 14–5, 67–83; U.S. Navy Dept., *History of the Bureau of Engineering of the Navy Department during the World War* (Washington, D.C.: U.S. Govt. Print. Off., 1922), pp. 47–54.

11. After moving to the United States before World War II, Chilowsky was involved in the exploration of plastic materials to replace the Rochelle salt crystals originally used in his piezoelectric work before and during the Great War. (See note 12 for a definition of the piezoelectric effect.) He was in contact with Dr. John Tate, head of Division 6 of the National Defense Research Council, in October of 1943 on this same subject. Chilowsky to Tate, 29 October 1943, box 61, Office of Naval Research—General Correspondence of the Coordinator of Research and Development 1941–1945, RG 298, NA; and John Herrick, *Subsurface Warfare: The History of Division 6, National Defense Research Committee*, chap. 5, NAS/Naval Studies Board Archive.

12. Langevin's device was a primitive transducer designed to send out a conical beam of sound from a surface ship or submarine with sufficient power to produce a return echo. This would enable the monitoring vessel to determine the location of the object causing the echo, whether iceberg, animal, ocean bottom, or submarine. The piezoelectric effect, upon which Langevin's work was based, is the generation of an electric polarization in certain crystals, Rochelle salt for example, by applying mechanical stress. Its converse—physical deformation of a crystal by the application of an electric charge—is the basis of the active sonar transducer.

13. K. T. Compton was attached to the Research Information Service, sometimes called the Research Information Committee, in Paris. Later in his career he became the president of the Massachusetts Institute of Technology and, during World War II, served on the National Defense Research Council.

14. Research Information Committee, Paris, to Research Information Committee, Washington, D. C., "Report of the Conference on Detection of Submarines by the Method of Supersonics" and "Report by Professor Morecroft on 'Historical Survey of Developments in the United States,' " Reports 161 and 161A, 31 October and 7 November 1918, respectively, box 11, Records of the NAS—Paris Report Series, RG 189, NA.

15. Dupree, p. 319; Willem Hackmann, *Seek and Strike: Sonar, Anti-Submarine Warfare, and the Royal Navy, 1914–54* (London: Her Majesty's Stationery Office, 1984); Bush, pp. 71ff.; and Marvin Lasky, "A Historical Review of Underwater Acoustic Technology 1916–1939 with Emphasis on Undersea Warfare," *U.S. Navy Journal of Underwater Acoustics*, October 1974, pp. 559–601.

16. The naval construction authorized by Congress in 1916 set out plans for ten battleships (32,000 tons, armed with eight 16-inch guns) and six battlecruisers (34,800 tons with 14-inch guns). In a second round of construction the Navy planned to build three more battleships; each would displace 42,000 tons and carry twelve 16-inch guns. The prospect of such naval power in American hands disturbed the British, French, and Japanese (George T. Davis, *A Navy Second to None: The Development of Modern American Naval Policy* [New York: Harcourt, Brace, 1940], pp. 230–1).

17. Davis, pp. 270ff.; and Robert Gordon Kaufman, *Arms Control in the Pre-Nuclear Era: The United States and Naval Limitation between the Two World Wars* (New York: Columbia Univ. Press, 1990). The agreed battleship ratio between Great Britain, the United States, Japan, France, and Italy was set at 5 : 5 : 3 : 1.75 : 1.75.

18. Hayes to Officer in Charge, Engineering Experiment Station, 19 February 1923, Navy 1924–1930, NAS—GOVT.: AG and Departments, NAS Archive.

19. Hydrography and oceanography are different. The former is closely related to physical oceanography, concentrating on physical conditions, boundaries, and currents. The latter is far more comprehensive and includes, among other things, the study of marine life, the physics and chemistry of the ocean, and the geology of the ocean bottom. In the U.S. Navy the function of the hydrographer was to incorporate physical oceanographic data in maps and sailing directions in order to improve navigation. Thus the naval commitment to oceanography addressed in this article represents a new and more comprehensive mission for the U.S. Navy Hydrographic Office.

20. Hayes to Officer in Charge, Engineering Experiment Station, 19 February 1923, Navy 1924–1930, NAS—GOVT.: AG and Departments, NAS Archive.

21. Annual Meeting, 21–22 April 1922, NRC, Division of Geology and Geography, NAS Archive.

22. Schlee, pp. 250-1; and Marc I. Pinsel, *150 Years of Service on the Seas: A Pictorial History of the U.S. Naval Oceanographic Office from 1830 to 1980*, vol. 1 (Washington, D.C.: Naval Oceanographic Office, 1981), pp. 110–1.

23. Halligan to Bureau of Engineering, 19 February 1923, Navy 1924–1930, NAS—GOVT.: AG and Departments, NAS Archive; and Hayes to Officer in Charge, Engineering Experiment Station, 19 February 1923, Navy 1924–1930, NAS—GOVT.: AG and Departments, NAS Archive.

24. Bassett to Denby, 14 March 1923; Bureau of Navigation to Secretary of the Navy [SecNav], 21 March 1923; Acting SecNav to Bureau of Navigation, 4 April 1923, Navy 1924–1930, NAS—GOVT.: AG and

Departments, NAS Archive. The Navy's Lieutenant Wilkes led the United States Exploring Expedition of 1838–1842.

25. Robert V. Bruce, *The Launching of Modern American Science, 1846–1876* (New York: Alfred Knopf, 1987), pp. 205ff.

26. Secretary of State to Denby, 22 January 1923; Davis to Denby, 30 April 1923, box 2431, SecNav Gencorr 1916–1926, RG 80, NA.

27. Fenneman to Denby, 30 April 1923, box 2431, SecNav Gencorr 1916–1926, RG 80, NA; Denby to Albert Barrows, secretary of the Division of Foreign Relations, NRC, 7 May 1923, Projects: Hydrographic Expedition—W.M. Davis, NRC: Foreign Relations: Committee on Pacific Investigations, 1923, NAS Archive.

28. Bassett to Asserson, 3 July 1923, box 2431, SecNav Gencorr 1916–1926, RG 80, NA.

29. Asserson to Chief of Naval Operations, 26 December 1923, box 2431, SecNav Gencorr 1916–1926, RG 80, NA. For general naval records on the Pan-Pacific Congress see file 253880, box 230, Gencorr 1907–1924, Naval Hydrographic Office, RG 37, NA.

30. Hobbs to Denby, 7 January 1924, Projects: Evaluation of Proposed Studies: Naval Oceanographic Expedition—W.H. Hobbs, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

31. Bassett to Gano Dunn, Chairman of the NRC Executive Board, 6 February 1924, and Dunn to Bassett, 9 February 1924, Projects: Evaluation of Proposed Studies: Naval Oceanographic Expedition—W.H. Hobbs, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

32. The Scripps Institution for Biological Research became the Scripps Institution of Oceanography, under Vaughan's direction, in October 1925. Barrows memorandum for the Members of the Committee on Pacific Investigations, 26 February 1924, Projects: Evaluation of Proposed Studies: Naval Oceanographic Expedition—W.H. Hobbs (Hobbs had neglected to inform the NRC of his proposed venture, thus Dunn, Barrows, and the committee members knew nothing of it before Bassett's communication), NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

33. Swingle to Barrows, 4 March 1924, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

34. Evermann to Barrows, 3 March 1924, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

35. Bowie to Barrows, 3 March 1924, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

36. The Hydrographic Office responded to Denby's request by soliciting opinions in forty differeot professional scientific and engineering societies. See William H. Hobbs, "A Proposed New 'Challenger' Exploring Expedition," *Science*, 7 March 1924, pp. 237-8, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive.

37. Memorandum for Hydrographic Office by Andrew C. Lawson, 17 March 1924; Research in Oceanography, Annual Meeting of the NRC, minutes, 26 April 1924, NRC Annual Meeting, 1924, NRC Division of Geology and Geography; Gregory (Chairman, Pacific Investigations Subcommittee) to Davis, 26 March 1924, Projects: Pacific Ocean Expeditions in Cooperation with the Navy Department, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive; Davis to Lawson, 29 February 1924, Navy 1924–1930, NAS—GOVT.: AG and Departments; and Andrew C. Lawson, "The Continental Shelf off the Coast of California," *Bulletin of the National Research Council*, April 1924, pp. 3-23, NAS Archive.

38. Ritter to Barrows, 4 March 1924; Merrill to Barrows, 3 March 1924; Evermann to Barrows, 3 March 1924; Barrows to Stejneger, 29 February 1924; Stejneger to Barrows, 27 February 1924; Swingle to Barrows, 4 March 1924; Vaughan to Barrows, 3 March 1924; Bowie to Barrows, 3 March 1924; Vaughan to Davis, 6 March 1924; Gregory to Barrows, 11 March 1924; Vaughan to Barrows, 26 March 1924; Dunn to Bassett, n.d. February 1924, NRC: Foreign Relations: Committee on Pacific Investigations, 1924, NAS Archive; and Vaughan to Barrows, 1 March 1924, Division of Geology and Geography, General Records, 1924–1925, NAS Archive.

39. Theodore Roosevelt, Jr., letter of the Secretary of the Navy inviting the conference, Navy Department, 2 June 1924, box 2432, SecNav Gencorr 1916–1926, RG 80, NA; and Report of the Conference on Oceanography, 1 July 1924; Bassett to SecNav, 6 October 1924, box 2432, SecNav Gencorr 1916–1926, RG 80, NA.

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